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Effect of foliar nutrients and plant growth regulators on quality attributes of Strawberry (*Fragaria* × *ananassa* Duch.) under naturally ventilated polyhouse

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Abstract
An experiment was conducted to study the effect of foliar nutrients and plant growth regulators on quality of Strawberry (*Fragaria* × *ananassa* Duch.) cv.Winterdawn under naturally ventilated polyhouse at Fruit Science Department, College of Horticulture, Mudigere (Zone-9 and Region-5) of Karnataka. The experiment was laid out in Completely Randomized Design with eleven treatments and three replications. Results of the study revealed that the maximum reducing sugars (4.48%) and total soluble solids (8.34 ^{o}B), non-reducing sugars (2.79%), total sugars (7.27%) and sugars: acid ratio (10.53) was recorded in T_5 ($ZnSO_4$ 0.6%). The maximum ascorbic acid (58.13 mg / 100 g) and maximum titrable acidity (0.78%) was recorded in T_9 (GA_3 150 ppm) it was onpar with T_8 (0.76%) and the maximum shelf life (2.89 days) was found in T_3 ($CaNO_3$ 0.6%), whereas, the minimum values for the above attributes were recorded in T_1 (control).

Keywords: Strawberry, winter dawn, total soluble solids, Reducing sugar, Shelf life

Introduction
Strawberry (*Fragaria* x *ananassa* Duch.) is one of the most delicious and refreshing soft fruits of the world, which belongs to Rosaceae family. It is known for its pleasant flavour, striking colour, and diverse blend of flavours. It is a short day plant, originated from France and the two American diploids *Fragaria chiloensis* and *Fragaria virginiana* are considered as its progenitors (Staudt, 1989) [6]. All cultivated varieties of strawberry are octaploid (2n = 56) in nature. Strawberry is a herbaceous, perennial, and stoloniferous herb with fibrous roots. The leaves have three leaflets, a saw toothed edge and are hairy. The flowers are white and borne in tiny clusters on slendour stalks that emerge from the leaf axil's surface creeping stem.
Strawberries contains over 90 per cent water, 7 per cent of carbohydrates, less than 1 per cent each of protein and fat and 2 per cent fibre. Fruit is fairly good source of vitamin A (60 IU / 100 g), vitamin C (30-120 mg/100 g), pectin (0.55%), iron, potassium, calcium, phosphorous, total soluble solids (7-12%), total sugars (5.0%) and acids (0.90-1.85%). Strawberry possess anticancerous compound called ellagic acid (Wange and Kzlogoz, 1998) [8].
Despite the numerous technology available to improve production, there is an issue with maintaining fruit quality. Due to its high degree of perishability and infection caused by many pathogens that can rapidly degrade fruit quality, strawberries have a very short shelf-life and senescent period. Foliar nutrients and growth regulators should be delivered at optimal concentrations to overcome these issues.
In strawberry, pre-harvest calcium application has been used commercially to improve quality and reduce postharvest decay. Boron is important for sugar translocation, reproduction and quality. Zinc is a crucial component of many enzymes and is necessary for normal plant growth and development. It is also required for the production of tryptophan, a precursor of IAA. Gibberellic acid promotes the transformation of long-day plants into short-day plants by enhancing vegetative growth and inducing early flowering. Gibberellins have been shown to affect both cell division and cell size. In strawberry fruits, the synthetic auxin NAA promotes fruitset, size, delays ripening, and boosts anthocyanin accumulation. The micronutrients and plant growth regulators together contribute to the quality of fruit at their optimum concentration.

Material and Methods
The experiment was carried out in naturally ventilated polyhouse at Fruit Science Department,

College of Horticulture, Mudigere (Zone-9 and Region-5) of Karnataka during the year 2018-2019. It is located between $13^0$25' North latitude and $75^0$25' East longitude with an altitude of 982 m above mean sea level. The research was laid out in completely randomised design (CRD) with three replications and eleven treatments [T_1- Control, T_2- Calcium nitrate (0.4%), T_3 - Calcium nitrate (0.6%), T_4 -Zinc sulphate (0.4%), T_5-Zinc sulphate (0.6%), T_6 - Boron (0.4%), T_7-Boron (0.6%), T_8-Gibberellic acid (100 ppm), T_9 -Gibberellic acid (150 ppm), T_{10}-Naphthalene acetic acid (25 ppm), T_{11} - Naphthalene acetic acid (50 ppm)]. The treatments in each replication were allotted randomly according to definite laws of probability. The experiment was carried out in pot of eleven inch size and planting was done on 01 November 2018. They were filled with thoroughly mixed potting mixture (soil: sand: FYM in 2:1:1) further treated with trichoderma (1 g/kg of media). The RDF @ 150:100:120 kg / ha was common for all the treatments, whereas per pot nutrient requirement was calculated and then applied to individual pots. The total plant population was 330 whereas, each treatment was allotted with eleven plants. The strawberry variety "Winter Dawn" was used for conducting experiment. Tissue culture plants procured from KF Bio Planter Private Limited, Haveli, Pune (Maharashtra). The quality analysis of the fruits at harvesting was done using standard method and procedure and was subjected to statistical analysis.

Results and Discussion

Total soluble solids (TSS), Reducing sugars, Non - reducing sugars, Total sugars and Sugars: acid

Significant difference with respect to quality parameters was recorded among treatments. The maximum reducing sugars (4.48%) and TSS (8.34 ^{o}B) was recorded in T_5 ($ZnSO_4$ 0.6%) followed by T_4 (4.12% and 7.79, respectively.). While the maximum non-reducing sugars (2.79%), total sugars (7.27%) and sugars: acid ratio (10.53) were recorded in T_5 ($ZnSO_4$ 0.6%) it was onpar with T_4 (2.76%, 6.88% and 10.26, respectively.) whereas, minimum reducing sugars (3.08%), non-reducing sugars (1.98%), total sugars (5.06%), TSS (6.54 ^{o}B) and sugars: acid ratio (7.55) was recorded in T_1 (control) and depicted in Table 1 and 2 respectively.

The increase in the content of sugars and TSS of fruits with $ZnSO_4$ might be attributed to the fact that zinc is beneficial in the process of photosynthesis which ultimately improved fruit quality. Zinc regulates the enzymatic activity and thus responsible for quicker metabolic transformation of starch and pectin in soluble compounds and rapid translocation of sugars from leaves to developing fruits leads to higher quality of strawberry fruits. Similar results were reported by Bakshi *et al.* (2013) [2], Yadav *et al*. (2018) [9] in strawberry.

Ascorbic acid and titrable acidity

The ascorbic acid content and titrable acidity of the fruits differed significantly between the treatments with the application of foliar nutrients and growth regulators (Table 1). The maximum ascorbic acid (58.13 mg/100 g) was recorded in T_9 (GA_3 150 ppm) followed by T_8 (55.51 mg/100 g). Whereas, maximum titrable acidity (0.78%) was recorded in T_9 (GA_3 150 ppm) it was onpar with T_8 (0.76%). While, minimum ascorbic acid (52.89 mg/100 g) and titrable acidity (0.67%) was recorded in T_1 (control). Increased ascorbic acid and acidity by use of gibberellins could be attributed to perpetual synthesis of glucose-6-phosphate throughout the growth and development of fruit which is the precursor of vitamin 'C'.

Further it is also related to activity of GA_3 increasing cell size and intercellular spaces coupled with accumulation of water, sugar and other soluble solids in greater amount as a result of translocation of metabolites towards the fruits which ultimately enhanced ascorbic acid content in fruit. These results are in close conformity with the results obtained by Sharma and Tiwari (2015) [5] in guava, Bhat *et al.* (2005) [3], Hazarika *et al*. (2017) [4] and Tiwari *et al.* (2017) [7] in strawberry.

Shelf life

Significant difference was observed among different treatments for shelf life of strawberry fruit (Table 2). The maximum shelf life (2.89 days) was found in T_3 ($CaNO_3$ 0.6%) and minimum shelf life was noticed in control *i.e.*, T_1 (1.92 days). This might be due to the fact that calcium being part of cell wall might have reduced tissue softening process and transpiration there by delaying the process of dissolution of middle lamella and disintegration of fibrillar material as well as and delayed senescence thus maintains fruit firmness, retardation of respiration rates in fruit helps in prolonging shelf life of strawberry fruits. This was in conformity with the findings of Amiria *et al*. (2009) [1] and Bakshi *et al*. (2013) [2] in strawberry.

Table 1: Effect of foliar nutrients and plant growth regulators on TSS, ascorbic acid, titrable acidity and sugars: acid ratio of strawberry

Treatments	TSS (^{o}B)	Ascorbic acid (mg/100 g)	Titrable acidity (%)	Sugars: Acid ratio
T_1 Control	6.54	52.89	0.67	7.55
T_2 $CaNO_3$ (0.4%)	7.56	54.85	0.74	7.77
T_3 $CaNO_3$ (0.6%)	7.65	55.51	0.75	8.28
T_4 $ZnSO_4$ (0.4%)	7.79	53.53	0.68	10.11
T_5 $ZnSO_4$ (0.6%)	8.34	55.27	0.69	10.53
T_6 Boron (0.4%)	7.29	54.52	0.71	8.14
T_7 Boron (0.6%)	7.57	55.22	0.73	8.52
T_8 GA_3 (100 ppm)	7.46	55.17	0.75	7.59
T_9 GA_3 (150 ppm)	7.53	58.13	0.78	7.61
T_{10} NAA (25 ppm)	7.06	53.36	0.70	8.32
T_{11} NAA (50 ppm)	7.38	53.37	0.72	7.69
S.Em ±	0.18	0.63	0.02	0.21
C. D. (P = 0.05)	0.53	1.89	0.05	0.61

Table 2: Effect of foliar nutrients and plant growth regulators on reducing, non-reducing, total sugars and shelf life of strawberry

Treatments	Reducing sugars (%)	Non -Reducing sugars (%)	Total sugars (%)	Shelf life (Days)
T_1 Control	3.08	1.98	5.06	1.92
T_2 $CaNO_3$ (0.4%)	3.52	2.23	5.75	2.84
T_3 $CaNO_3$ (0.6%)	3.96	2.25	6.21	2.89
T_4 $ZnSO_4$ (0.4%)	4.12	2.76	6.88	2.24
T_5 $ZnSO_4$ (0.6%)	4.48	2.79	7.27	2.45
T_6 Boron (0.4%)	3.46	2.32	5.78	1.96
T_7 Boron (0.6%)	3.92	2.30	6.22	2.00
T_8 GA_3 (100 ppm)	3.35	2.27	5.62	2.33
T_9 GA_3 (150 ppm)	3.66	2.28	5.94	2.46
T_{10} NAA (25 ppm)	3.11	2.72	5.83	2.50
T_{11} NAA (50 ppm)	3.30	2.24	5.54	2.66
S.Em ±	0.11	0.05	0.15	0.05
C.D. (P = 0.05)	0.31	0.14	0.44	0.14

Conclusion

On the basis of results obtained in the present investigation, it can be concluded that the foliar application of $ZnSO_4$ (0.6%) has shown best results for quality parameters, boron (0.6%) improved the better fruit shape and calcium nitrate (0.6%) proved good shelf life of strawberry. Thus, considering better quality and maximum cost benefit ratio, foliar application of GA_3 (150 ppm), zinc sulphate (0.6%), boron (0.6%) and calcium nitrate (0.6%) along with RDF could be safely adopted by the farmers in cultivation of strawberry cv. Winter dawn under protected cultivation. Apart from the best treatments, GA_3 (100 ppm), zinc sulphate (0.4%), boron (0.4%) and calcium nitrate (0.4%) was registered better interms of quality of strawberry.

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